

KNOWLEDGE-BASED SYSTEMS IN JAPAN

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Edward Feigenbaum, Stanford University (Panel Chair)

Robert S. Engelmores, Stanford University (Report Editor)

Peter E. Friedland, NASA Ames Research Center ✓

Bruce B. Johnson, Andersen Consulting

H. Penny Nii, Stanford University

Herbert Schorr, University of Southern California

Howard Shrobe, MIT

SUMMARY

This report summarizes a study of the state-of-the-art in knowledge-based systems technology in Japan, organized by the Japanese Technology Evaluation Center (JTEC) under the sponsorship of the National Science Foundation and the Advanced Research Projects Agency. The panel visited 19 Japanese sites in March 1992. Based on these site visits plus other interactions with Japanese organizations, both before and after the site visits, the panel prepared a draft final report. JTEC sent the draft to the host organizations for their review. The final report was published in May 1993, and is available from the National Technical Information Service as NTIS Report PB93-170124 (see inside back cover for ordering information). A more extensive summary of the panel's findings is being prepared for publication in *AI Magazine*.

RATIONALE, OBJECTIVES AND DESIGN OF THE STUDY

Expert Systems (ES), also called Knowledge-Based Systems (KBS) or simply Knowledge Systems, are computer programs that use expertise to assist people in performing a wide variety of functions, including diagnosis, planning, scheduling and design. These systems have become the most successful commercial applications of Artificial Intelligence (AI) research, first in the United States, and then in Europe and Asia. Thousands of systems are now in routine use world-wide, and span the full spectrum of activities in business, industry and government. Economic gain has been realized along many dimensions: speed-up of professional (and

semi-professional) work; cost savings on operations; return on investment; improved quality and consistency of decision making; new products and services; captured organizational know-how; improvements in the way a company does its business; crisis management; and stimulation of innovation.

Because of the potentially large impact that knowledge systems technology can have on the economy, and because Japan has had active and well-funded research and commercialization activities in KBS since 1982, the National Science Foundation and the Advanced Research Projects Agency requested that a study be conducted of the state-of-the-art of knowledge-based systems in Japan.

The primary objectives of this JTEC panel were to investigate Japanese expert systems development from both technological and business perspectives and to compare progress and trends with similar developments in the United States. More specifically, there were five dimensions to the study:

1. Business sector applications of expert systems
2. Infrastructure and tools for expert system development
3. Advanced knowledge-based systems in industry
4. Advanced knowledge-based systems research in universities
5. National projects, including:
 - ICOT – the laboratory of the Japanese Fifth Generation Computer Project;
 - EDR – the electronic dictionary research knowledge-base building effort;
 - LIFE – the Laboratory for International Fuzzy Engineering.

The panel conferred with Japanese computer scientists and business executives both before and after the official visits of March 1992. The 19 sites visited included four major computer manufacturers, eight companies that are applying expert systems to their operations, three universities, three national projects, and the editors of *Nikkei AI*, a publication that conducts an annual survey of expert systems applications in Japan.

CONCLUSIONS

The panel reached the following conclusions about the state-of-the-art in knowledge-based systems in Japan.

Business Sector Applications, Infrastructure and Tools

On the basis of our site visits, plus additional data gathered by *Nikkei AI*, we can draw a number of conclusions about the state of the art of expert system applications within the business sector in Japan.

1. The technology of expert systems has now been mastered by the Japanese. Since the early 1980s, when they first entered this field, they have completely caught up with the United States. Their best applications are equal to the best elsewhere in the world. Their use of the technology is widely spread across many business categories.
2. Computer manufacturers play a dominant role in the technology and business of expert systems. The Japanese have mastered and absorbed expert system technology as a core competence. They tend to use systems engineers rather than knowledge engineers to build systems. Consequently, integration with conventional information technology poses no special problem for them, and is handled routinely and smoothly, without friction. These large computer companies also build many application systems for their customers; small firms play only a minor role in applications building, in contrast with the situation in the United States.
3. Within the computer manufacturing companies, there is a close coupling between activities in the research laboratories, the system development groups, and the sales departments. The development and sales groups work closely together to develop custom systems for clients, the results of which are fed back to the research lab to provide the requirements on the next generation of ES tools.
4. Viewed as a technology (rather than as a business), the field of expert systems is doing well in Japan, as it is in the United States. As in the United States, the experimentation phase is over, and the phase of mature applications is in progress. Following a normal learning curve, the number of successful deployments of expert systems has risen sharply, from about 5% in the early years to about 75% in recent years. Japanese appliers of the technology make eclectic use of AI techniques (their attitude seems to be, "Try it, it might work."). Most of these techniques originated in the United States or Europe. As in the United States, expert systems technology is often a component of a bigger system. The Japanese do not attempt to analyze payoff at the component level, but at the system level. Thus they do not measure the return on investment of these embedded expert systems. However, there are many applications in which the expert system is the main technology.
5. Viewed as a business, the expert systems field did not "take off" in any exceptional way versus the United States or Europe. Although the overall level of activity is significant and important, there is no evidence of exponential growth. The components of the business consist of expert system tools, consulting, and packaged knowledge systems. Hitachi's expert system business seems the most viable. Other major players, such as Fujitsu and CSK, have not had business success.

6. With respect to tools for building knowledge-based systems, the Japanese tools are similar in sophistication to those sold and used in the United States. The techniques and methodology developed in the United States have been and continue to be made into products quickly.
7. Japan has more experience than the United States in applications of KBS technology to heavy industry, particularly the steel and construction industries.
8. Aside from a few exceptions, the Japanese and U.S. ES tool markets follow similar trends: vertical, problem-specific tools; a move towards open systems and workstations; and an emphasis on integration of expert systems with other computational techniques.
9. The number of fielded applications in Japan is somewhere between 1000 and 2000, including PC-based applications. The number of U.S. applications is probably several times that of Japan.
10. Fuzzy control systems (not counted in the above tally) have had a big impact in consumer products (e.g., camcorders, automobile transmissions and cruise controls, television, air conditioners, and dozens of others).
11. We saw continued strong efforts by Japanese computer companies and industry-specific companies (e.g., Nippon Steel) to advance their KBS technology and business. This situation contrasts with that in the United States, where we see a declining investment in knowledge-based systems technology: lack of venture capital, downsizing of computer company efforts, few new product announcements. It is a familiar story, and one for concern, as this trend may lead to Japanese superiority in this area relatively soon.

Knowledge-Based Systems Research in Japan

1. A survey of three years of working papers of the Special Interest Group on Knowledge-Based Systems of the Japan Society for AI shows a wide range of research topics, touching most of the subjects of current interest in the United States.
2. The quality of research at a few top-level universities in Japan is in the same range as at top-level U.S. universities and research institutes.
3. In the remainder of the Japanese university system the quality of research is not at the same level as at first or second tier U.S. research centers.
4. The quantity of research (in terms of number of projects and/or number of publications) is considerably smaller (by nearly an order of magnitude) compared to the United States.

5. LIFE is the world leader in applying fuzzy logic concepts to classic AI core problems.
6. The industrial laboratories appear to be doing advanced development that is tightly coupled to application or product development. The computer companies and some high-tech companies are carrying out some knowledge-based systems research, but most non-computer companies do none. We saw, essentially, a thin layer of excellent work at Hitachi, Toshiba, NEC, Fujitsu and NTT, and (on previous visits) also at IBM Japan and Sony. The most basic and deep work is at Hitachi's Advanced Research Laboratory, which is conducting advanced research in model-based reasoning and machine learning.

ICOT

1. Using massive parallelism, ICOT appears about to achieve its stated goal of 100 million logical instructions per second (LIPS) theoretical peak performance.
2. The Fifth Generation Project achieved its goal of training a new generation of computer technologists.
3. ICOT is one of only a few sites in the world that is studying massively parallel *symbolic* computing.
4. ICOT created the funding and motivation to spur significant interest worldwide in AI, KBS and advanced computing paradigms.
5. ICOT's logic programming research is world class, and probably the best in the world.
6. On the negative side, ICOT made little progress in the applications dimension, and has had little impact on knowledge-based systems technology.
7. The choice of Prolog and logic programming, coupled with high-cost research machines, isolated ICOT from industry.

EDR

1. EDR will likely produce a practical scale, machine usable dictionary for Japanese and English.
2. With several hundred thousand entries in their concept dictionary, the scale of EDR accomplishments is very impressive and should be taken as a model for similar research programs elsewhere.

3. A follow-up project, the Knowledge Archives project, may be funded, and should be closely tracked.
4. EDR has not significantly improved the underlying technology for maintaining large knowledge bases, nor significantly added to our theoretical understanding of knowledge base organization.

Comparisons with the United States

A comparison of expert systems activities in Japan and the United States, drawn from the above conclusions, is presented in the following two tables.

TABLE 12
Comparison of Applications of Expert Systems
in the United States and Japan
 (See Key, p. 44)

| | Current State | Trend |
|--------------------------|--------------------------|--------------|
| Quality of the best | 0 | = |
| Quantity relative to GDP | 0 | -> |
| Support Structure | + | = |
| Tools | 0 | -> |
| Consumer Products | + | -> |
| Integration | + | * |

* Japan trend is constant or gaining

TABLE 13
Comparison of Knowledge-Based Research
in the United States and Japan
 (See Key, p. 44)

| | QUANTITY | | QUALITY | |
|-----------------------------------|---------------|-------|---------------|-------|
| | Current State | Trend | Current State | Trend |
| Adv. KBS Research in Industry | | | | |
| Basic Research | - | = | - | = |
| Applied R&D | 0 | -> | + | = |
| Adv. KBS Research in Universities | - | -> | - | -> |
| National Initiatives | | | | |
| Parallel Symbolic Computation | + | <- | + | = |
| Very Large Knowledge Bases | + | <- | 0 | = |
| Fuzzy Logic Systems | + | -> | + | = |